EARLY MARS CRATER DEGRADATION PROCESSES: AUTOMATED CRATER WALL SLOPE MEASUREMENTS AND REGIONAL TRENDS IN TYRRHENA TERRA. Benjamin D. Boatwright[1], James W. Head[1], and Mikhail A. Kreslavsky[2], [1]Dept. of Earth, Environmental, and Planetary Sciences, Brown University, Providence, RI 02912 USA, [2]Dept. of Earth and Planetary Sciences, University of California Santa Cruz, Santa Cruz, CA 95064 USA (benjamin_boatwright@brown.edu; james_head@brown.edu; mkreslav@ucsc.edu).

Introduction: Impact craters can be used as a record of past and present geomorphic processes on planetary bodies. On airless bodies such as the Moon, crater degradation has been described as a topographic *diffusion* process caused primarily by impact bombardment on the surface, leading to net downslope transport of unconsolidated material under the influence of gravity [1-5]. Diffusive crater degradation is generally accepted to occur on Mars [6-8], but unlike the Moon, the exact mechanism is not known with certainty. For early Mars, geomorphic evidence points toward diffusive rainsplash accompanying precipitation in a warm and wet climate [7,9]. Impact cratering has not been widely considered in the context of diffusive degradation on Mars, even though it has inevitably played a role in shaping the surface throughout its history [10]. We previously presented evidence that impact bombardment on Mars could have made a significant contribution to diffusive crater degradation, even in a 1-bar atmosphere [11]. We have subsequently improved our diffusive degradation model to account for a number of crater production and emplacement effects [12]. Past studies have identified *wall slope lowering* as a potentially unique indicator of diffusive crater degradation on Mars that can be distinguished from *advective* or *aggradational* processes [6-8]. In order to quantify the extent of this degradation, and thus the potential contribution from impact bombardment, an efficient measurement technique to obtain crater wall slopes from topographic data is necessary. Here, we describe a new automated method for crater wall slope retrieval that will be used to create a catalog of crater wall slope data for Mars, and we perform an initial study of wall slope statistics for a small population of craters in the Tyrrhena Terra region.

Automated crater wall slope retrieval: The method we have developed closely follows Kreslavsky & Head's [13] crater wall slope retrieval algorithm for MOLA PEDR point data spaced at 300 m/pix. We use HRSC stereo DTMs down to 75 m/pix for our analysis to increase spatial coverage and resolution. We employ the Robbins & Hynek [14] Mars crater database to select craters for further analysis. For our initial study, we limited our selection to craters with a simple morphology, D = 1–7 km. Fassett et al. [15] and other studies have demonstrated that complex craters with terraced walls on the Moon do not fit a linear diffusive profile, suggesting that there may be a significant nonlinear component in the degradation of larger craters; we assume that a similar phenomenon may be true for Mars. We have chosen Tyrrhena Terra as a study area due to its combination of high crater density and minimal fluvial dissection and dust cover.

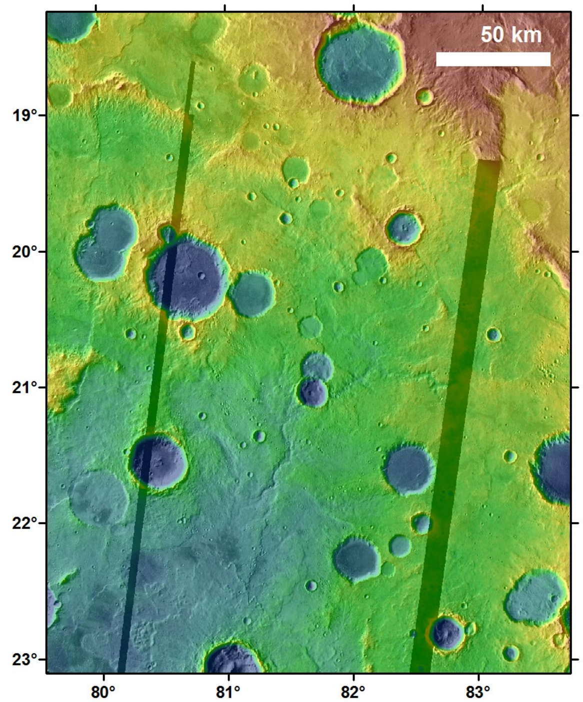

Fig. 1. THEMIS daytime IR mosaic with HRSC elevation overlay of the Tyrrhena Terra study area.

Our study region (Fig. 1) comprises the overlapping footprints of four HRSC stereo DTMs with an area of ~6.7×10^4 km^2. For each crater, we used ArcMap geoprocessing tools to extract a square matrix of elevation values centered on the crater with dimensions 3x the crater diameter to ensure full coverage of the crater. The extracted DTM was imported into a MATLAB script that automated the measurement of crater wall slopes in the image. The crater center locations in the Robbins database, which mostly relied on THEMIS daytime IR images, are misregistered slightly with the map-projected HRSC DTMs, an error that can become quite substantial for smaller crater sizes. We developed an empirical search algorithm to find the true minimum point of the crater with a weighting function for the distance of a point from the measured center. The algorithm is less accurate either when a crater is too shallow or too obscured to confidently determine a center point, or when an otherwise well-defined crater does not have a topographic minimum at its center (e.g. a central mound or other infill). Correctly identifying the crater center visually in the DTM is important for obtaining accurate wall slope information. For the measurement of the wall slopes themselves, we require two fixed reference points such that wall slopes can eventually be compared between craters at different stages of degradation. In order to do this, we have chosen to measure the average wall slope taken from the rim crest to the base of the crater wall. These positions are found using the points of minimum and maximum topographic curvature, respectively, along a radial profile extending outward from the crater center. The wall slope is measured in this manner in four cardinal directions, and the maximum of these values is taken as the representative diffusive wall slope for the crater. We use the maximum instead of the mean because there are often large variations in wall slope within the same crater. Simple craters are particularly susceptible to modification or obliteration by later impacts due to their smaller size; the maximum wall slope is therefore the most likely to represent the part of the crater that has been least modified by these processes.

Regional trends in Tyrrhena Terra: The studied population consists of 288 craters with diameters 1–7 km. 78% are smaller than 2 km, which is lower than the 87% predicted by the Neukum production function (NPF) [16]. This means that the size-frequency distribution of studied craters is shallower than the production function, suggesting that some smaller craters were preferentially obliterated [e.g. 17]. The SFD corresponds to a Late Noachian age for craters $D > 2$ km and an Early–Late Hesperian age for craters $D < 2$ km [18]. The maximum observed wall slope is 41° with a median value of 12°, followed by an abrupt cutoff below ~5°. This cutoff is likely to be due to the obscuration of craters once their walls become extremely shallow. Wall slope histograms for the subpopulations of larger and smaller craters are shown in Fig. 2. (The Kolmogorov–Smirnov statistical test rejects a random nature for the difference between the distributions with a p-value of 10^{-17}.) The distribution for smaller craters has a pronounced peak at moderate slopes and a tail of steep slopes; the median slope is 10°. Diffusive degradation is more effective for smaller craters [2,4-5], resulting in a gentler median slope. The peak at gentler slopes and narrow tail of steeper slopes suggests that steep slopes degrade faster, then degradation slows. The subpopulation of larger craters has a very wide distribution of retrieved slopes with a median of 23°. The wider distribution results from slower degradation due to larger size and the presence of older, Noachian to Early Hesperian craters, which experienced intensive degradation prior to the Early Hesperian.

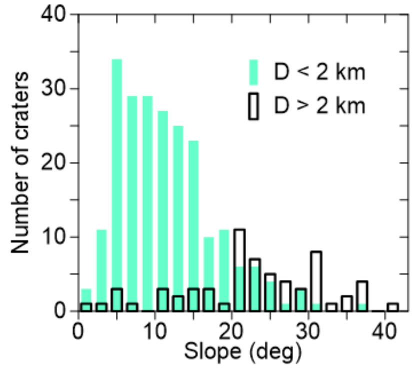

Fig. 2. Histogram of maximum wall slope for subpopulations of larger and smaller craters; slope binned by 2°.

Beyond these first-order trends, the evolution of crater wall slopes on Mars is not entirely straightforward. The wall slope of an individual crater may represent the effects of many discrete events with disparate causes. Instead of single craters, we may look to the wall slope distribution of entire populations with different surface ages to determine how the statistics of the distribution have evolved, and how this compares to our understanding of wall slope evolution due to a specific process such as topographic diffusion. This is a similar approach to Fassett & Thomson [4] for the Moon, who used the distribution of degradation states for crater populations of different ages to determine how the rate of diffusive degradation had evolved through time.

Future work: This study is the first step in an ongoing process to characterize the degradation of small craters on Mars. Using fresh crater topography as an initial condition, we intend to carry out numerical simulations of diffusive crater degradation on Mars in order to assess the potential significance of impact bombardment in comparison to other climate-dependent processes such as rainsplash, which has been invoked to explain diffusion in a warm and wet early Mars climate [7,9]. In combination with other ongoing work [19], these simulations will test to what extent a warm and wet early Mars climate is necessary to explain morphometric observations of ancient surface features.

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